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THIS ISSUE

Hydraulic Valve Lifters in Passenger Car Engines

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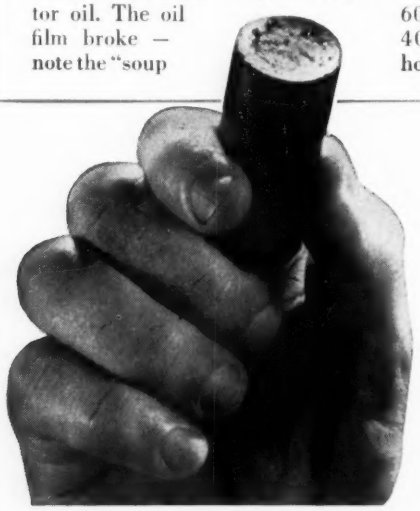

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LUBRICATION

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Hydraulic Valve Lifters in Passenger Car Engines

Valve Operating Mechanisms

All currently-manufactured American passenger car engines are of the "four-stroke" or "four-cycle" type, i.e., they require a total of four movements of each piston or "strokes" to prepare for and produce a single useful power stroke. A professor of thermodynamics would (correctly) define them as "integral reciprocating heat engines using air as the working media." Translated, this means that these engines convert the heat energy of gasoline into useful power by burning it with atmospheric oxygen in a confined space (the combustion chamber) and forcing the resultant hot high-pressure gases to push against a piston and rotate the engine's crankshaft. The theoretical description of the process is simple enough but its practical application involves numerous knotty details that thousands of competent engineers over sixty years have not yet solved to their entire satisfaction.

Early engines employed an "automatic" intake valve with a spring so weak that the valve was pulled open by vacuum alone when the piston moved downward on its intake stroke and returned to its seat on beginning of compression. Such a valve was charmingly simple (since it needed no gear to open and close it), but it was also woefully inefficient since it throttled or strangled the incoming charge thereby preventing the cylinder from obtaining a full charge. Such an engine not only failed to approach even the very modest power expected of it in those days, but it also refused to run very fast and was cantankerously sensitive to any change in either load or speed. In short the automatic intake valve was useful only where load and speed were both modest and relatively constant, – definitely *not* the characteristics of automotive service. Engineers soon sensed the shortcomings of the automatic valve and realized the necessity for some necessarily more complex method of precisely opening and closing the intake valve in close coordination with piston movement.

All modern passenger car engines utilize at least two "poppet" or tulip valves (an intake and an exhaust) to properly regulate the flow of gases through each cylinder. These valves are kept closed by strong springs and must therefore be opened at a proper time by exerting mechanical pressure on them. The particular arrangement of valves used in

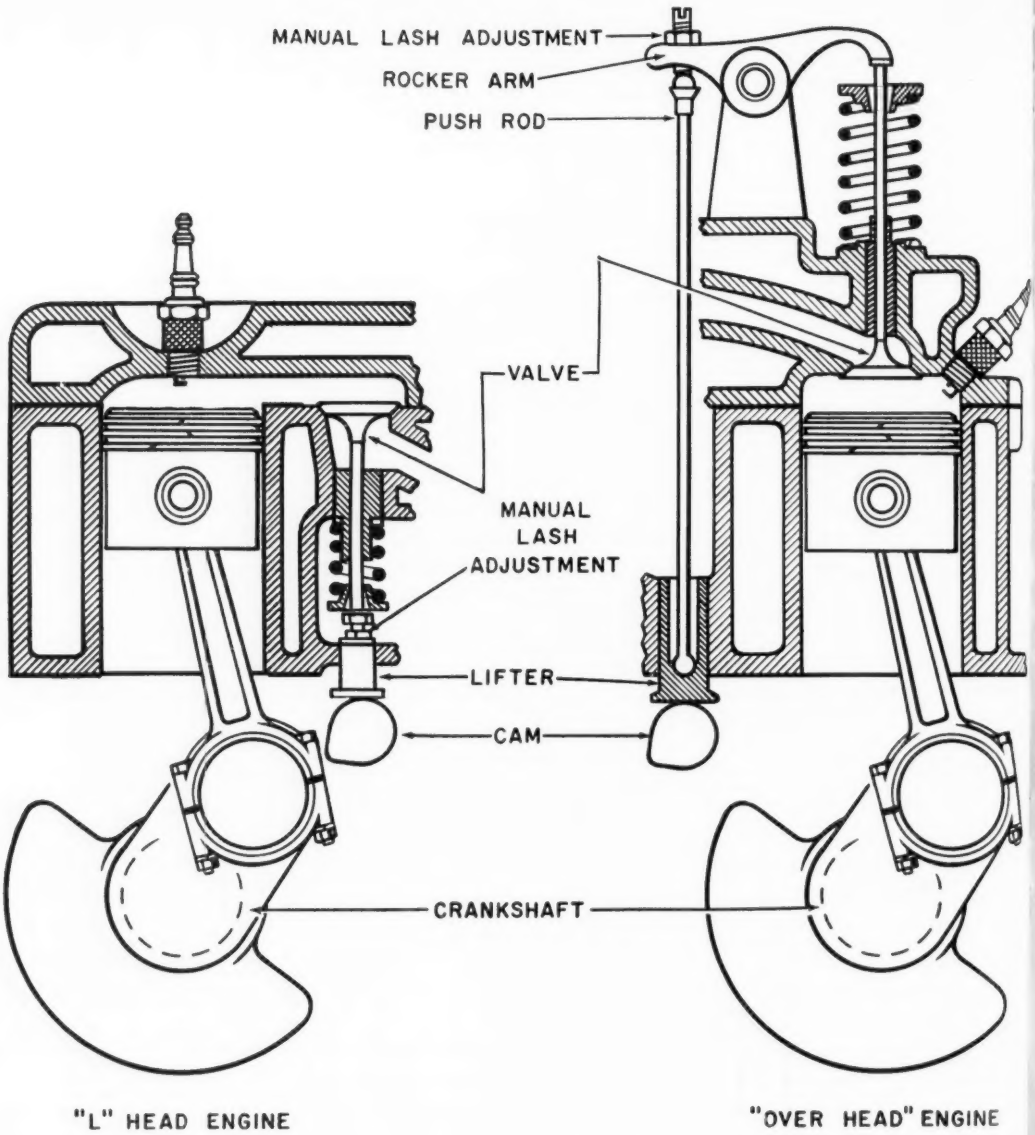


Figure 1 — Schematic Diagrams of "L" Head and Overhead engines illustrating the considerable inherent differences in length, mass, springiness, and differential thermal effects that are found in two types of valve trains.

a cylinder has originated such engine types as the "L" head, "overhead" (OH), "F" head and even an historic "T" head. Figure 1 illustrates a section across one cylinder of the more common overhead and "L" head types; since the second valve lies immediately behind the single one shown, both valves cannot be conveniently illustrated. With either of the diagrams of Figure 1 in mind let us now examine Table I and notice the nice interaction or "timing" that must be obtained betwe valves and piston to develop maximum pow This timing is effected by means of a cam for ea valve mounted on a cam shaft that in four cy engines is driven at half the crankshaft speed.

In Table I the discerning reader may have notic a supposed contradiction in the fact that both t intake and exhaust valves are actually open simu taneously for a short period between the exhau

TABLE I

PISTON AND VALVE ACTION IN A FOUR-CYCLE ENGINE

("TC" and "BC" refer to top and bottom center positions of piston. Letters "A" and "B" indicate "after" and "before". Figures in parentheses are range of timing in 1954 cars and grand average expressed in crankshaft degrees.)

Stroke	*Piston Movement*	*Valve Actions*		*Promotes Maximum Power By*
		Intake	*Exhaust*	
Intake	Downwards	Open	Closes shortly *after* top center (5° to 45.7° ATC; 15.0° ATC)	Filling cylinder with maximum weight of combustible mixture.
Compression	Upwards	Closes *after* bottom center (39° to 99.7° ABC; 54.4° ABC)	Closed	Compressing mixture as much as possible without inducing uncontrolled ignition such as detonation or preignition.
Ignition and Power	Downwards	Closed	Opens before bottom center (42 to 70° BBC; 52.2° BBC)	Igniting mixture before top center, burning in a controlled manner, and expanding exhaust gases against piston to force it downward and to rotate crankshaft.
Exhaust	Upwards	Opens slightly before top center (26.8° BTC to 1° ATC; 13.6° BTC)	Open	Preparing for the following intake stroke by expelling as much of the hot exhaust gases as possible.

and intake strokes. Such a condition is called "overlap" or simply "lap" and (as we will see) is a deliberate concession to permit the development of maximum power at high engine speed. Like all other physical materials, both the air-gasoline mixture and the subsequent exhaust gases have definite weights or "masses" hence in conformance to basic physical law (Force = mass times acceleration) a force must be applied to cause them to change velocity, i.e., to accelerate or decelerate. In other words any mass (and gases are no exception) tends to maintain its velocity (velocity being defined as speed in a definite direction) unless a force is applied to change either or both speed and direction. At the close of the exhaust stroke, and even though the exhaust valve is closing and the piston is starting downward again, the exhaust gases are still flowing out of the cylinder at considerable velocity: if allowed to continue a little longer, they can purge or "scavenge" the cylinder more effectively in preparation for the intake charge.

When the intake valve starts to open, the intake charge in the manifold is stationary; at high engine speeds it cannot accelerate rapidly enough, particularly through a still-opening intake valve, therefore the designer helps it by giving it more time, i.e., by starting to open the intake valve *before* top center. Thus at high engine speeds a considerable intake-exhaust valve amount of overlap is very advantageous, but at low engine speeds—and par-

ticularly at idle where the difficult combination of low speed and closed throttle exists—excessive valve overlap will cause rough idling and even stalling. With automatic transmissions a dependable and stable engine idle is more necessary than ever. For maximum speed and power, racing engines use very large overlaps, hence they won't even run (much less idle) at low speeds. The engineer must therefore make a careful compromise on valve lap, but his meticulous experimentation is wholly lost *unless the selected valve timing is rigidly maintained regardless of wide variations in engine speed, load and temperature.*

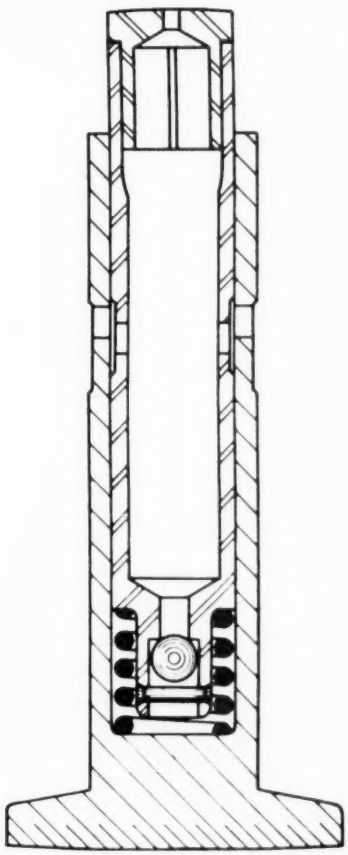
Effect of Timing, etc.

Let us now consider the very important and interrelated effects of valve timing "lash", engine design, materials and engine operating conditions.

First and always a valve must always close and seal completely: any appreciable leakage between a valve and its seat not merely lowers efficiency, but allows the valve to be quickly destroyed by burning or "guttering". Remember that the valves are required to seal-in combustion gases that have a temperature in excess of 3000°F. The valves themselves are only prevented from also reaching such high temperatures by the cooling effect of contact with their seats, their guides, and cooler gases flowing by. Exhaust valves normally and successfully operate at red heat for long periods as long as they continue to seat and seal.

At such elevated temperatures even the most suitable valve alloy is much weaker and many times more vulnerable to oxidation, corrosion and erosion than at room temperature. Let anything prevent or delay complete seating for more than a few cycles and the valve is irrecoverably destroyed. The obvious function of a valve operating mechanism or "valve train" is to *open* the valve at the proper time; but it is at least equally important that the valve be permitted to *close* again.

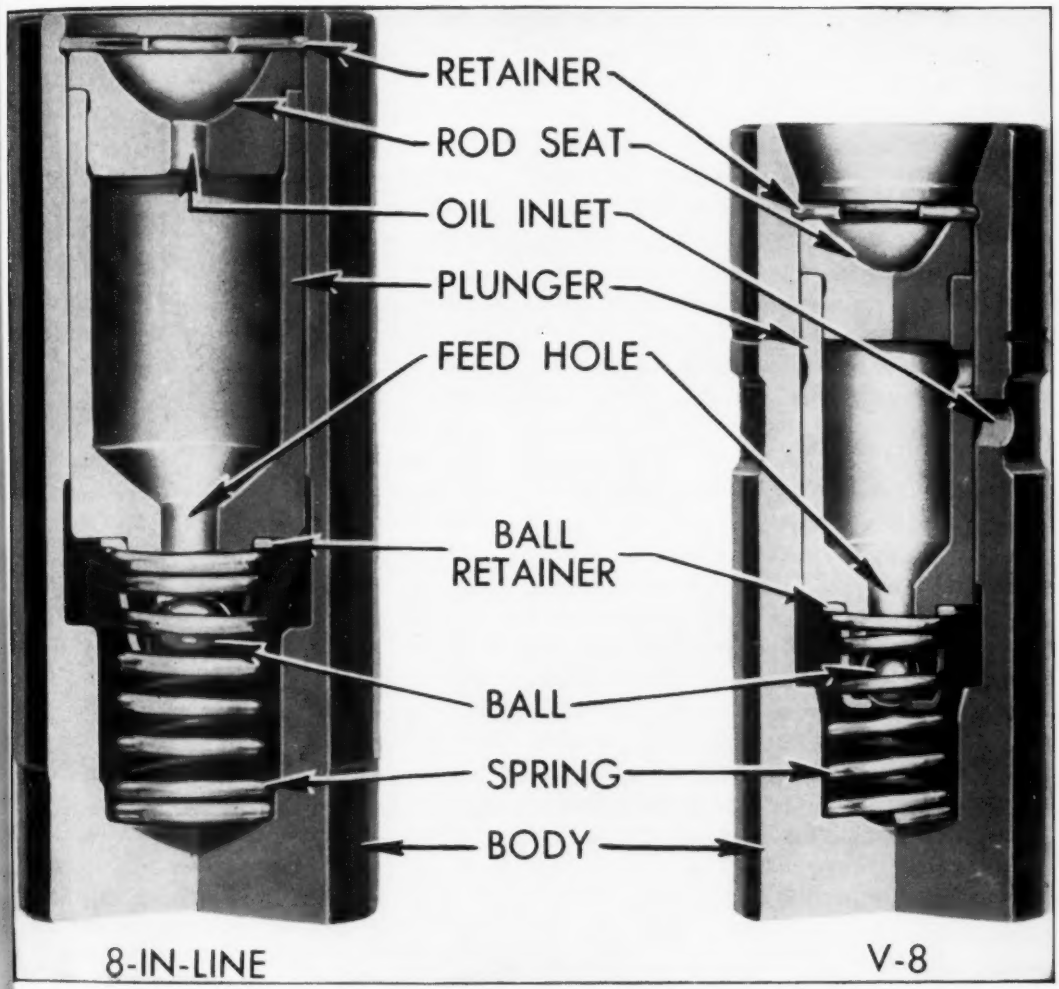
The minimum permissible lash is the algebraic sum of all clearances, plus all springiness due to bending or deflection of the several parts plus changes in dimension of the entire system due to differential thermal effects. The first two effects can either be calculated or easily measured, but differential thermal effects are so involved and transient that very special optical-mechanical or strain gage instrumentation and actual tests are required. The lat effect alone is responsible for striking differen between intake and exhaust valves. The histo method of obtaining valve train neutrality is determine the lash experimentally and manu adjust more than enough clearance, or lash into system to insure maintenance of some positive l under any and all operating conditions.



Courtesy of Eaton Manufacturing Comp

Figure 2 — Early integral type hydraulic valve lifter w mushroom face.

To illustrate the variability of differential therm effects, measurements made on one overhead va engine with adequate valve lashs showed that after a cold start, the exhaust valve lash *decrea* rapidly to subnormal value, due to rapid heati and expansion of the valve stem. As engine war up continued, jacket coolant temperature increase the engine block expanded and lash *increas* abnormally. As engine oil temperature slowly creased, the push rod expanded and lash *decrea*



Courtesy of Buick Motor Division, GMC.

Figure 3 – Representative integral barrel-type hydraulic valve lifters.

slowly to the normal value. Closing the throttle caused rapid cooling of the exhaust valve and corresponding rapid increase in lash followed by slower further increase as the block cooled.

Valve lash is plainly a nuisance. Insufficient lash will quickly burn valves. On the other hand, too much lash not only gives a very noisy engine with decreased smoothness and lowered power, but the consequent violent valve train accelerations will in time cause expensive valve stretching or breakage, valve seat pounding, cam shaft damage and lifter scuffing. The most desirable amount of lash is *none at all*, provided of course that such "zero lash" is accurately and automatically maintained during all operating conditions. During the years several mechanical and hydraulic "no-lash" devices have been invented to accomplish this. The earliest mechanical devices employing the somewhat variable friction characteristics of the wedge (or screw) were too expensive to enjoy wide usage, however development has quietly continued and new devices can be expected.

"Valve lifter" and "valve tappet" are regarded as different names for the same article. In subsequent discussion "valve lifter" will be used.

Hydraulic No Lash Lifters

In 1913 Bollee patented the original hydraulic automatic lifter and furnished the apt description "takes the play out of the valve train without

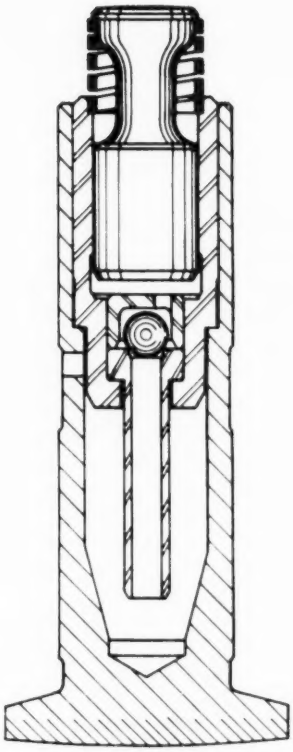
entirely disposing of it". The first commercial application of a hydraulic lifter apparently did not occur until 1933 when Pierce Arrow began to use the remarkably simple lifter illustrated in Figure 2. During the ensuing fifteen years all of the higher priced, most of the medium priced cars, and even some of the "light" cars adopted hydraulic lifters. It is significant that not one of these car builders ever reverted to solid lifters; on the contrary uncounted hundreds of improvements have been made to engines, lifters, filters, service methods, and lubricating oils to further increase the already high satisfaction of the whole.

How Do They Work

Regardless of manufacturer or design, all hydraulic lifters used to date require a constant supply of clean lubricating oil from the engine's own supply system, and all depend on the fact that oil is practically incompressible. Either of the "integral type" hydraulic lifters illustrated in Figure 3 can be used to demonstrate the application of this principle.

All lifters consist of a piston or "plunger" closely fitted into but freely slideable within a cylinder or "body" with a lower chamber left between plunger and body. The retainer ring as shown is merely an assembly convenience to keep all of the carefully matched lifter parts together.

When properly installed and operating in the engine, the plunger must never come close to the retainer ring which would artificially restrict its range of movement. A light or easily-compressed spring in the lower chamber attempts to push the plunger upward out of the body. The bottom of the plunger is fitted with a check valve which allows free flow downward *into* the lower chamber but prevents reverse flow upward *out* of it. If the compressible air in the lower chamber is now completely replaced with incompressible oil, even a very large load applied *suddenly* to the plunger will not force it into the body. On the other hand, the continued application of a moderate load during a longer interval will force a tiny amount of oil up through the tiny clearance between plunger and body, and permit the plunger to move downward by a corresponding amount. *It is this minute but controlled leakage and corresponding plunger movement that gives the hydraulic lifter its automatic adjustment ability.* Either too much or too little



Courtesy of Eaton Manufacturing Compan

Figure 4 — Hydraulic valve lifter with mushroom face and removable hydraulic unit.

leakage, or a sticking plunger will prevent proper hydraulic lifter operation. If the engine is running this normal and necessary leakage can be seen as a series of puffs of fog-like oil vapor above each lifter.

For a detailed account of hydraulic lifter operation revert again to the overhead valve engine diagram of Figure 1 and assume that its conventional solid-iron lifter has been replaced with a hydraulic one like the "V-8 type" in Figure 3. The unnecessary manual lash adjustment screw may either be removed or simply ignored. Engine oil at moderate pressure is fed to this type of lifter through a drilled gallery which communicates with the circumferential groove around the outside of the lifter body. Oil enters the hollow plunger through one or more "oil inlet" holes and forces any air up past the loosely-fitted "rod seat".

At the instant of engine operation shown in Figure 1, the lifter spring assisted somewhat by engine oil pressure has already removed all lash

from the valve train by gently pushing the plunger upwards. The total effect of lifter spring and oil pressure is negligible in comparison to the opposing and very strong engine valve spring, hence there is no tendency for the engine valve to open under such tiny forces. As the plunger moves upward however, sufficient oil is sucked down through the ball check valve to solidly fill the lower chamber.

As the engine continues to rotate, the bump or "lobe" of the cam begins to force the lifter upwards to open the engine valve. Oil in the lifter lower chamber momentarily tries to escape upward past the ball check valve but closes it almost instantly. The small amount of leakage that occurs during closure of the ball check is an advantage in that it automatically introduces a small but positive lash of say 0.002 inches.

Continued pressure on the lifter during both the opening and closing phases of the engine valve causes a small additional amount of oil leakage up past the plunger. When the engine valve is fully closed and the lifter again contacts only the "base circle" of the cam, a small but finite amount of lash has therefore accumulated in the valve train. This developed "leakage" lash is ordinarily more than adequate to absorb any *increase* in valve train length that has occurred during the preceding three cycles. In the unlikely event that a negative lash has developed during the preceding strokes, the lifter has ample time during the following three "resting strokes" to "leak down" under pressure of the valve spring and neutralize the lash.

In brief, a hydraulic lifter automatically (and almost instantly) adjusts its own length to compensate for any net change in valve train length. Though often erroneously called a "zero lash lifter", it actually operates with a small but finite positive lash. To operate properly it must receive adequate amounts of clean oil, its plunger must be able to move freely throughout its operating range, the ball (or other type of) check valve must seat promptly and completely, and a controlled amount of oil leakage must occur between plunger and body.

Types of Hydraulic Lifters

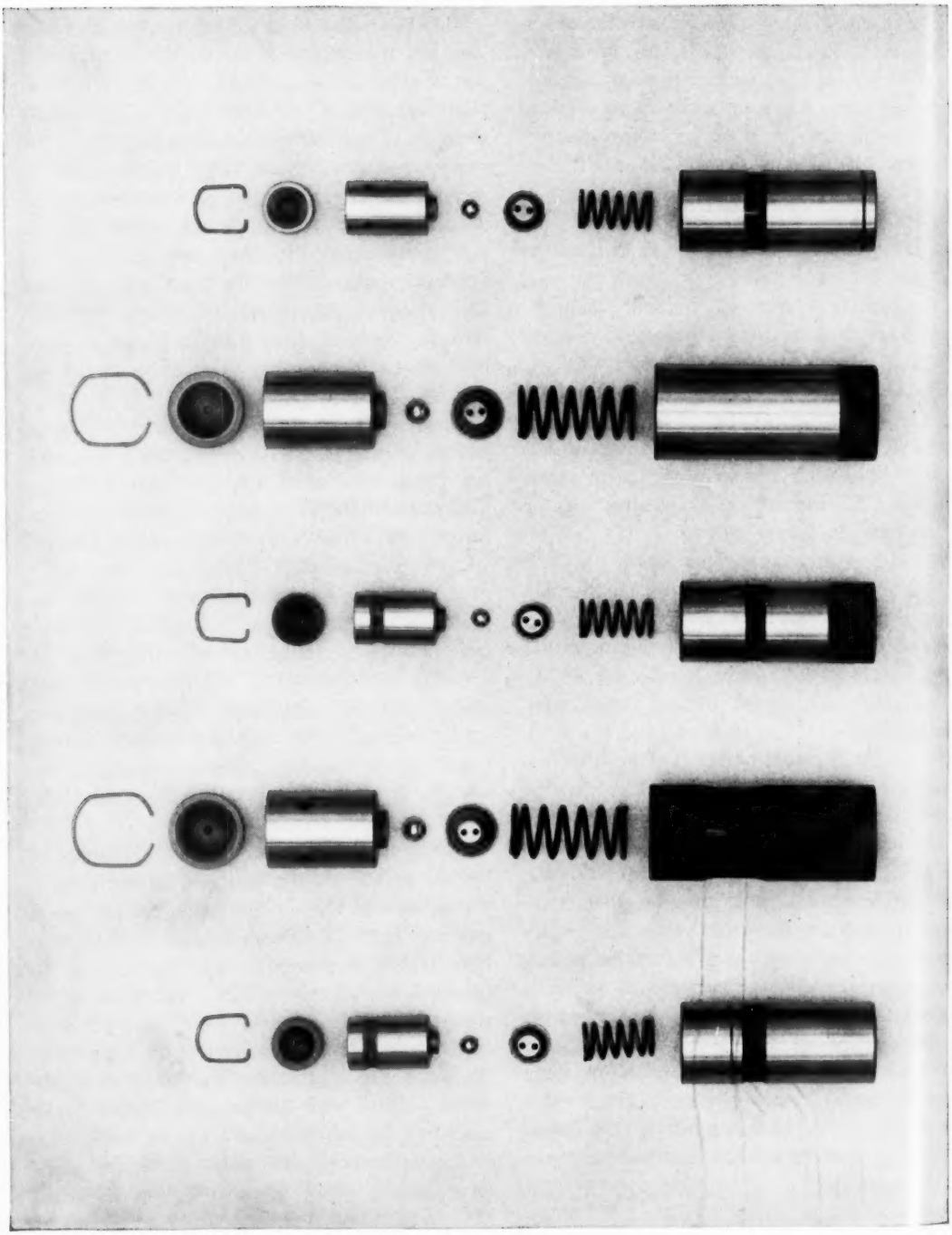
Because of the utility value, literally hundreds of different types of hydraulic lifters have been developed. While it is obviously beyond the scope of this article to attempt a complete catalog, examination of a few representative types is profitable.

The lifter illustrated in Figure 2 was of the "integral type" in that the interior of its body served as a bore for the plunger while the exterior operated in the lifter guide. The "mushroom face" on this type should restrict its use to engines having removable lifter guides, otherwise a major engine disassembly including removal of the cam shaft would be required to merely take out a lifter. To reduce lifter and cam shaft wear it is frequently desirable to chill-cast or otherwise harden the mushroom face. Obviously the near proximity of such hard material makes accurate machining of the adjacent plunger bore even more difficult.

Another characteristic of the integral type is its lack of adaptability since it must be designed for the dimensions of a specific engine. During the early introductory days of limited usage in a few engines of relatively low production, the restricted adaptability of the integral type was a great handicap; to overcome both this and the previously mentioned removal handicap, the lifter manufacturer originated the "removable type" illustrated in Figure 4. In this type the plunger, body spring and check valve were combined in a small "hydraulic unit" which slid easily into the top of a wide variety of different lifter bodies and could be easily removed from the top without disturbing the lifter body.

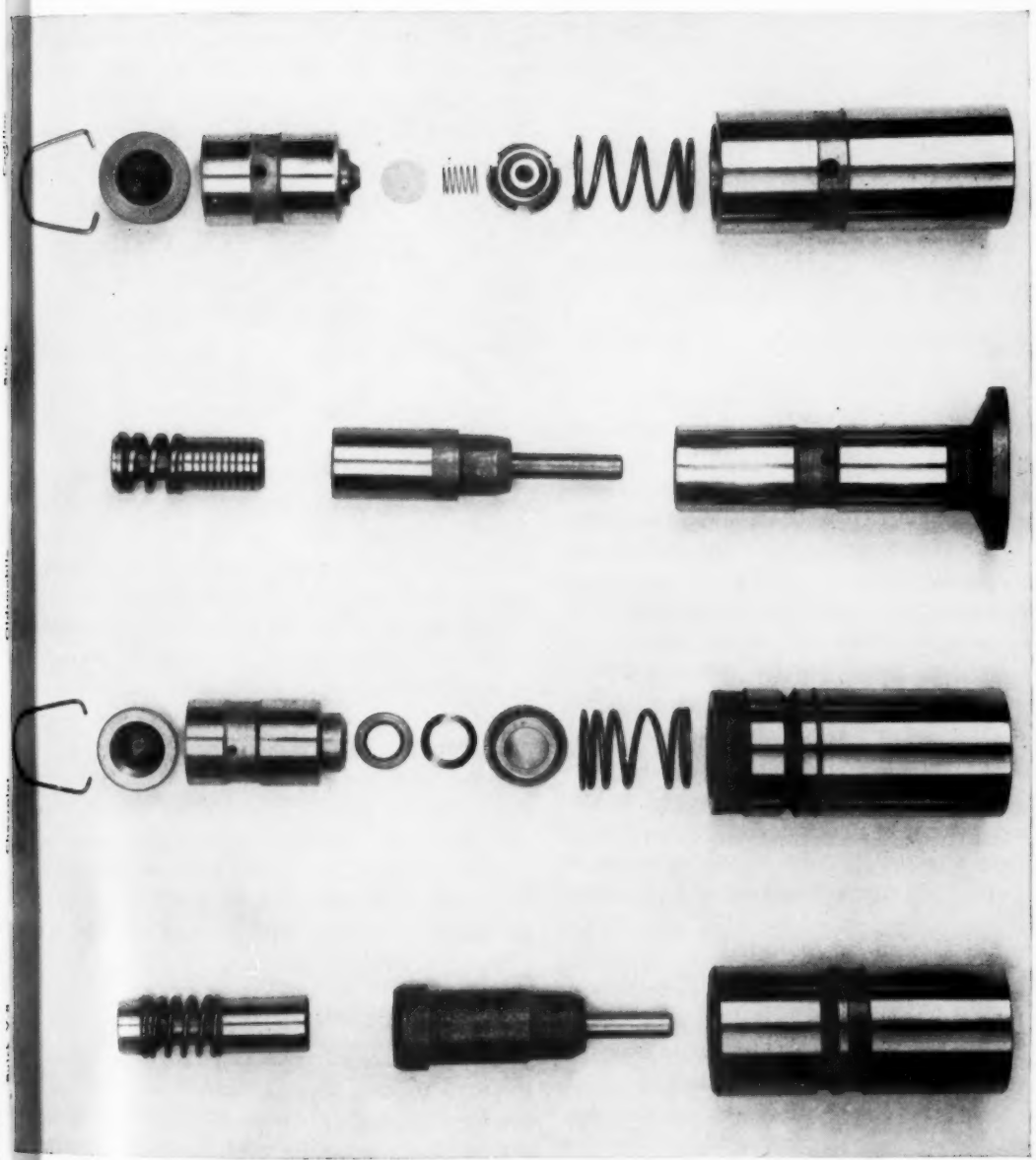
The spring of the hydraulic unit is fastened to the top of the plunger and can not be removed without special tools. Furthermore the ball check normally rests *on* its seat, and its movement is restrained by a pressed-in cage that can not be removed. The characteristic tube below the ball is used to extend the effective "reach" of the hydraulic unit and to assist in separating air from oil in the lower supply chamber. In passing let it be mentioned that while the hydraulic lifter is usually placed at the cam shaft end of the valve train, similar hydraulic devices are available for placement in such other positions as the top end of the push rod and within either end of the rocker arm.

The lifters illustrated in Figure 3 are of the integral type but "barrel style" which is now almost universal. Absence of a mushroom head greatly facilitates service operations since the bar-



Courtesy of Diesel Equipment Division, GMC.

Figure 5 — Representative integral barrel-type hydraulic lifters from modern automotive engines.



Courtesy of Eaton Manufacturing Company

Figure 6 — Representative integral and removal-unit hydraulic lifters from modern automotive engines. Note flat valves in second and fourth barrel lifters.

rel lifter can be drawn out of the top of the now-common integral or non-removable lifter guide. To further facilitate removal, the lower part of the lifter body (which extends beneath the lifter guide) is sometimes machined to a slightly smaller diameter. It should also be noted that the left hand lifter in Figure 3 receives its oil supply from the rocker arm through a hollow push rod.

Figures 5 and 6 are "exploded" views of hydraulic lifters used in several 1953 and 1954 model cars. And speaking of explosions, the incautious or inept removal of the retainer ring in any of those illustrated in Figure 5 will spread precious parts all over the shop.

SERVICE EXPERIENCE AND LUBRICATION

The *total* clearance between the plunger and body of an hydraulic lifter is only about three ten-thousands of an inch, or a tenth the diameter of a hair. No other complex automotive part is so closely fitted or finely finished; and furthermore there are either twelve or sixteen hydraulic lifters in the engine. Small wonder that such mechanical jewels should be first to respond and protest driver abuse and carelessness. The real marvel is that of the millions of hydraulic lifters in service, only a small percentage give any trouble.

Unlike most other mechanisms, an ailing hydraulic lifter gives fair advance warning of impending trouble by clicking, and conveniently it continues to make its noise when the engine is idling and other engine noises are at a minimum.

Some Click Is to Be Expected

Clicking of temporary duration is a perfectly normal thing: only that clicking which lasts several minutes after starting the engine should be cause for concern and methodical investigation. And never forget that other engine parts can also emit similar clicking noises to thoroughly confuse the issue.

When any engine is stopped, some of its valves are bound to be open: with solid mechanical lifters, these valves will remain open indefinitely or until the engine is restarted. With hydraulic lifters however, those lifters that are holding valves open are subjected to heavy valve spring pressure and will "leak down" to their minimum length at which point the plunger strikes a shoulder or the bottom of the lifter body. When the engine is restarted, those lifters that have been forced to "leak down" will click until they receive enough oil from the engine's lubrication system to reestablish minimum lash. Naturally such lifters will require more time to quiet down on a cold morning since the engine oil will be viscous and will not supply the lifters as quickly.

Excessive Click a Sign of Trouble

Even in warm weather, but immediately after engine crankcase oil has been drained and replaced, lifters may click for several minutes after restarting. This is due to the fact that when the old oil is drained, the suction side of the engine oil pump is also drained, consequently it is full of air. This rather large bubble of air must be forced through the engine's supply system and the lifters inevitably will receive some of it. Since air is easily compressed, even a small bubble in a hydraulic lifter will cause clicking until the lifter has purged itself. Too high a crankcase oil level, an air leak on the suction side of the engine oil pump or an inadequate type of crankcase oil will also cause oil foaming. If oil foaming occurs, hydraulic lifters will click indefinitely and until the cause of foaming has been corrected.

Long-continued or permanent clicking is much more than a mere annoyance; if allowed to click loudly or "hammer" without correction for very many miles, the faulty lifter may break a valve and wreck the entire engine. The fact that the afflicted cylinder will produce little or no power is of *minor* consequence.

Effect of Type of Driving

Lifter troubles rarely occur in engines that are subjected to long trips or heavy load operation; on the contrary they are much more frequent in engines that are mainly used for short trips or "stop and go" driving. The real significance of these two facts is just beginning to be realized.

Unfortunately, stop and go driving is now the rule rather than the exception. A recent nation-wide survey showed that two-thirds of all passenger car trips are less than 8 miles long. Under such operating conditions an engine never gets

warm enough nor operates with sufficient throttle opening to completely burn even the best gasoline.

Gasoline is a complicated mixture of more than a hundred different "hydrocarbons," which are chemical compounds containing only hydrogen and carbon. When completely burned or "oxidized," the hydrogen in the gasoline produces more than the gasoline's original volume of water while the carbon forms harmless carbon dioxide (CO_2 or soda water gas), both of which pass out of the exhaust system as harmless vapors.

On the other hand, a cold engine, particularly if it operates at idle or part throttle, will partially burn only part of the gasoline while transforming the remainder into sticky varnish-like materials, potent organic acids and liquid diluent. That portion which only partially burns forms water, black carbon "fuel soot," and deadly poisonous carbon monoxide (CO) gas. Of all these nasty partial-oxidation and polymerization products, only the carbon monoxide gas passes completely out the exhaust system, while most of the remainder are trapped in the oil film on the cylinder walls and scraped down into the crankcase oil by piston ring action. Further contamination is provided by gray lead ash from the anti-knock compound which likewise tends to remain in the engine under such poor operating conditions.

These vicious contaminents can cause a nightmare of troubles such as corrosion of bearings and other "soft" metals, emulsion sludges that clog oil passages, rusting of iron and steel parts, scuffed, clogged and stuck piston rings, very high piston ring and cylinder bore wear, and fuel varnish coatings on all surfaces that are not actively rubbing *unless prevented by a suitable oil.* Excepting the carbon and lead ash, the other contaminants are at least partially and temporarily soluble in lubricating oil and pass unchanged through the best of oil filters.

Fuel varnish is especially harmful to hydraulic lifters because of its devilish tendency to become insoluble and to deposit light brown films on those lifter plunger and body surfaces *that are not actively rubbing at that particular moment. Any subsequent change in engine operation that requires the hydraulic lifter to change its operating length will force the plunger over a fuel varnish film and cause it to stick.*

Importance of Oil Quality

While it may seem that the crankcase oil is only an innocent party caught amid all of these crimes, it can frequently be charged with contributory negligence. In other words, the oil may be blamed not for what it *actually did*, as much as what it *failed* to do.

Almost all of the engine manufacturers that use hydraulic lifters sensed the import of this complex situation and began to recommend the exclusive use of heavy duty type motor oils. Furthermore, and for the first time in automotive history one manufacturer began to factory-fill his cars with a high quality heavy duty motor oil instead of the historic inexpensive straight mineral oil. Other manufacturers quickly followed.

While a well balanced high quality heavy duty type motor oil has many desirable characteristics such as oxidation resistance, rust and corrosion protection, acid neutralization, foam prevention, and wear reduction, the hydraulic lifters particularly appreciate its high detergent-dispersant properties which are primarily responsible for controlling the evil effects of fuel varnish and carbon deposition. In fact experience indicates that the higher the detergent characteristic the better, i.e. "Supplement One" oils are considerably better than the normal Heavy Duty.

Drain Period Important

Since a heavy duty oil has a fairly definite maximum capacity for assimilating contaminants, and since it is the most inexpensive insurance against trouble, the car owner must be encouraged to drain it at frequent regular intervals. If the car is operated under "stop and go" conditions, a drain period of only 500 miles coupled with frequent filter changes are most advisable.

Often a mere change of oil — even to a poorer oil — may free a stuck lifter, but the permanence of this cure depends on the type of the new oil. The substitution of even a straight mineral oil will occasionally free a stuck lifter, but resticking usually occurs very promptly. Furthermore, and because of the low flow rate of oil through a lifter, the presence of a straight mineral oil within the lifter will considerably postpone the curative action of a highly detergent oil that has been subsequently added to the crankcase. The fact that

the lifter stuck in the first place is pretty good evidence that the oil used with it either did not have sufficient detergent-dispersant quality when new, or had been used entirely too long.

Lifter Cleaning Procedure

Frequently a badly stuck lifter can only be freed by removing it from the engine, disassembling it, and carefully removing all fuel varnish or other foreign materials using only a suitable solvent and gentle wiping with a soft clean cloth. Any more drastic cleaning method will change the fits and ruin the lifter. Since they are carefully matched or "selectively assembled" by the manufacturer, the parts of any lifter must be kept strictly separate from all others until reassembled.

Too often a mechanic will not take the time or trouble to positively identify the particular lifter that may be stuck and will remove and replace *all* of the lifters in the engine with new ones. In spite of careful directions by the car manufacturer, very few lifters are disassembled and cleaned. As a consequence of these poor practices, a recent survey by one manufacturer showed that more than 90% of the "defective" lifters returned to him by garages were actually in perfect working condition, and practically all of the remainder could have been restored to full usefulness by simply cleaning them.

It has been previously mentioned that to operate properly a hydraulic lifter must be able to "leak down," but neither too fast nor too slow. Each car manufacturer makes available to his service agencies the equipment, instructions, materials, and specifications necessary for a "leak-down" test. Though details vary, the general method of conducting a "leak down" is to fill the lifter completely with a special fluid of low but standardized viscosity, apply a standard load or force to the plunger, rotate either plunger or body slowly and measure the time required for the plunger to "leak down" or descend a specified distance. In general it is good practice to test both new and overhauled lifters before installing them in an engine, and to refrain from using any that do not "leak down" within the time limits established by the car manufacturer.

As both a preventive and cure for stuck hydraulic lifters, several car manufacturers and major oil refiners are distributing "additive concentrates" in refinery-sealed quart or pint motor oil cans. These additive concentrates are strong solutions of identical or similar detergent-dispersant additives used by the refiners in manufacturing their own heavy duty and Supplement One motor oils. These are legitimate materials of proven effectiveness and must not be confused with the host of widely advertised proprietary "cure-alls" of doubtful value and excessive cost.

CONCLUSION

The hydraulic valve lifter is one of the most important components of the modern passenger car engine. On the other hand it is one of the least understood and consequently most abused. The purpose of this article is to promote better understanding of the benefits of this mechanism. The greatest satisfaction will result where it is constantly supplied with clean oil of the proper type.

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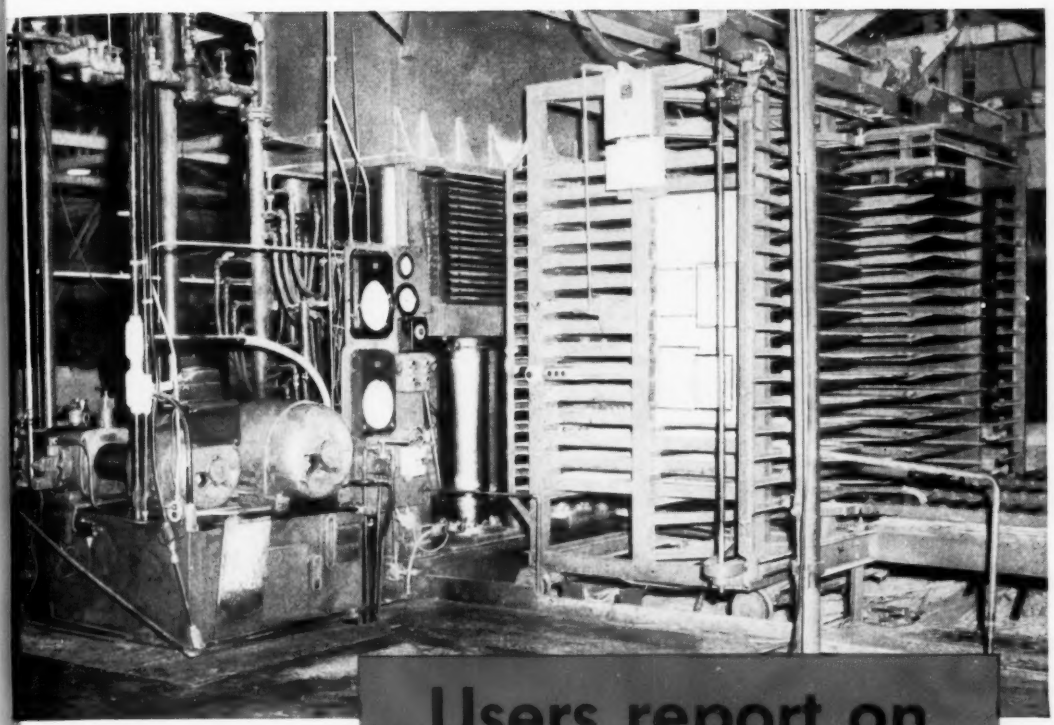

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A user of hydraulic die casting machines*: "After four years of service, we found the original *Texaco Regal Oil R&O* still in perfect operating condition. It was absolutely free of sludge and the entire system perfectly clean."

A manufacturer of hydraulic equipment*: "I have yet to see one of our units in which *Texaco Regal Oil R&O* has been used that wasn't clean, free from rust and sludge—with pump parts, piping, controls all in A-1 condition."

A user of hydraulic hot presses*: "*Texaco Regal Oil R&O* has kept our hydraulic systems clean . . . we have never had a shutdown due to rust, sludge or foam. Pump wear has been negligible."

Use *Texaco Regal Oil R&O* in your hydraulic mechanisms and get the same fine results. Tests prove that *Texaco Regal Oil R&O has more than ten times the oxidation-resistance* of ordinary turbine-quality oil used in hydraulic service—plus far greater rust- and foam-inhibiting ability.

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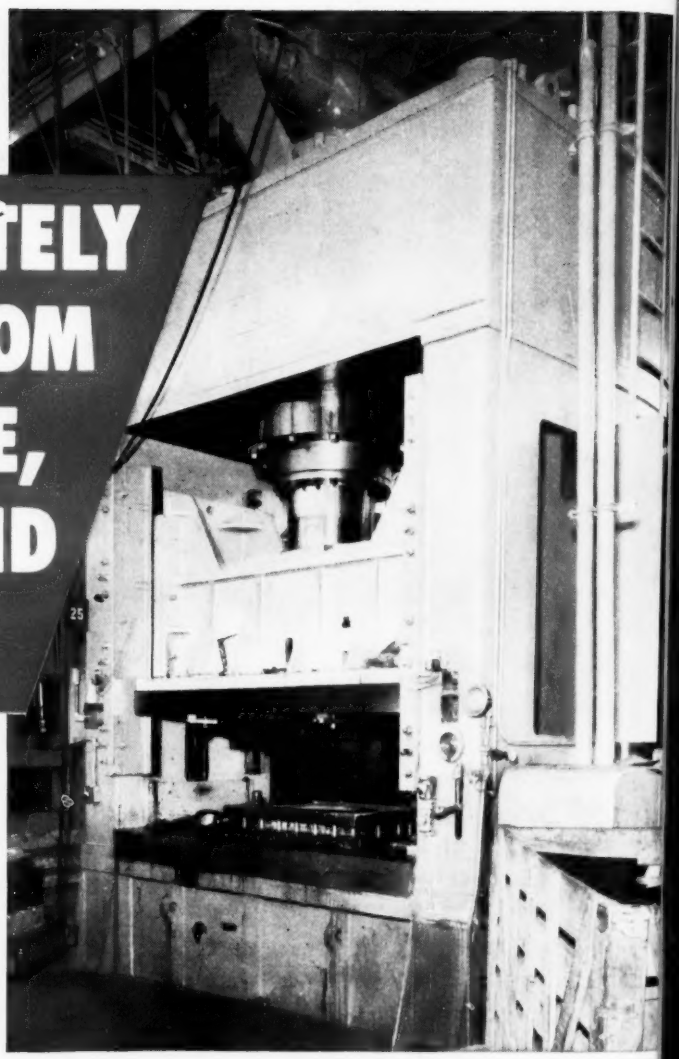
"COMPLETELY FREE FROM SLUDGE, RUST AND FOAM"



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3—*"In spite of severe service . . . the press has never had to be down for repairs."*

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